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COMBINED FLUID-AIR EVAPORATOR AND NOVEL SWITCHING CONCEPT  
FOR A HEAT PUMP IN A VENTILATING APPARATUS

TECHNICAL AREA

The present invention relates to a combined fluid-air evaporator, which is preferably usable as a refrigerant evaporator for a ventilation arrangement provided for buildings. For this purpose, the term "fluid" comprises, in the expanded definition, all phase states of materials with the exception of the solid phase, and thus particularly the liquid phase and also the gas phase. A preferred integration of the combined fluid-air evaporator with a heat pump is also described.

BACKGROUND INFORMATION

In newly constructed apartment houses, strengthened ventilating apparatuses having heat reclamation are increasingly installed, which result in higher living comfort, since the required air exchange is ensured automatically and the temperature level of the intake air is significantly raised by the heat reclamation. Through the targeted exploitation of the used air heat to preheat the intake air using an air-air heat exchanger, the heating operation for a building may be reduced and therefore energy may be saved.

Ventilating apparatuses having installed heat pumps, which are conceived for heating the intake air and an accumulator, such as an industrial water accumulator, and thus operate as used air heat pumps, are also known. In a way known per se, heat is transferred from the building used air to an outside air flow, which is typically cooler, using an air-air heat exchanger, before the building used air cooled during the heat transfer is fed to the evaporator of the heat pump, so that the cooled building

used air is subjected to further heat absorption before it is released to the environment as exhaust air. Particularly in the case of lower temperatures, at which the cooled building used air flows through the evaporator of the heat pump, icing frequently occurs within the evaporator, through which the function of the heat pump is disadvantageously influenced until breakdown, so that suitable measures are to be taken to counteract corresponding occurrences of icing.

For example, in the case of already occurring icing or for the purpose of prevention in times of elevated icing danger, the used air flow flowing through the evaporator of the heat pump is additionally heated using gas heating or electrical heating. This measure is not only connected to an energy input, which is relevant to cost, but rather additionally requires a constructively complex heating component which is to be provided in the flow direction of the used air flow before entering the evaporator of the heat pump.

In addition to the above wish for the most economic intake air heating possible, particularly during the cold time of year, there is additionally the wish for effective and economic cooling of the living spaces during summertime outside temperatures. A demand in this regard is reflected in the increasing sales numbers of at least slightly efficient split devices, which are suitable for both room cooling and also intake air heating.

If ground heat exchangers, in the form of air-ground registers or closed brine loops, are used, passive precooling of the building intake air may also be achieved by thermally coupling warm intake air with the ground temperature, which is significantly lower than the air temperature, in the summertime. In addition, it is possible using a heat pump to increase the passive

precooling described above because of the significantly higher cooling performance of the heat pump. However, for this purpose four-way valves or three-way valves having possible leaks are required within the complicated loop systems in which heat pumps are integrated. The use of expensive solenoid valves is also known, through which the cooling loop becomes more complicated, more expensive, and more susceptible to breakdown. In addition, upon changeover between heating and cooling operation of the heat pump, the cooling loop briefly becomes unstable, which results not only in reduction of the performance number of the heat pump, but rather in addition causes reduction of the service life of the compressor.

However, above all in typical air-water heat pumps, the icing of the evaporator represents a large problem. The heat pump is not equipped with an air-air heat exchanger (as is the case in a compact ventilation air conditioner), and the air for the evaporator is thus not preheated by the room used air and icing frequently occurs at low outside temperatures, i.e., an air-water heat pump usually may only be operated efficiently down to outside temperatures of approximately  $-5^{\circ}\text{C}$  (depending on the manufacturer). Thawing must be performed very often below the specified outside temperatures, however, through which the performance number of the heat pump worsens. In order to counteract this, it is expedient to heat further bivalently using an additional heat source, for example, in the form of electrical heaters or using oil or gas boiler heaters.

#### DESCRIPTION OF THE INVENTION

The present invention is based on the object of specifying an achievement of the object specified above, so that changing over between heating and cooling operation of a heat pump integrated in a building ventilation arrangement is possible using means which are as technically simple as

possible to implement. The icing occurring in the known heat pumps is to be largely avoided, and the operational reliability and also the service life of the components participating in the loop of heat pumps are particularly to be improved.

The achievement of the object on which the present invention is based is specified in Claim 1, which describes a combined fluid-air evaporator, whose use as an evaporator element within a heat pump represents the refinement according to the present invention of a ventilator arrangement for buildings described in Claim 8. Features advantageously refining the idea according to the present invention may be taken from the subclaims and the further description with reference to the exemplary embodiments.

The achievement of the object according to the present invention is based on a novel evaporator concept, which is particularly suitable for use as a refrigerant evaporator within a heat pump. The novel evaporator concept may be referred to as a combined fluid-air evaporator and has at least two separate duct systems, through which separate material flows may be directed. At least one of the two duct systems has a free surface, which is preferably to be brought into thermal contact with an air flow. Both duct systems are additionally at least partially in joint thermal contact.

The combined fluid-air evaporator according to the present invention thus differs from a typical air evaporator in that a further duct system is provided, through which a further, additional heat source, in the form of a material flow, preferably a liquid flow, may be used for the evaporation procedure.

In the simplest exemplary embodiment, the combined fluid-air evaporator is implemented as a coaxial pipe system,

which provides a first pipeline, in which a second pipeline runs internally. The internal pipeline thus separates a first duct system from the second duct system, which is formed by the volume enclosed by both pipes.

Separate material flows, preferably separate liquid flows, which are in thermal contact with one another over the entire length of the pipe system via the pipe inner wall, may be introduced through both duct systems.

An alternative embodiment of the combined fluid-air evaporator according to the present invention provides a single pipeline, which has an internal partition wall that partitions the pipeline along its entire extension into two pipeline halves. In this case as well, two material flows passing through the particular pipeline halves come into thermal contact with one another through the internal partition wall and, in addition, heat transfer between the individual fluid flows and an air flow flowing around the pipeline is ensured.

Advantageous interconnections of the duct systems and/or applications of different fluid flows, as well as preferred technical applications, will be discussed in the following with reference to the exemplary embodiments. Finally, the combined fluid-air evaporator according to the present invention allows thermal contact between an air flow flowing around the external pipeline and two different fluid flows.

For the preferred use of the combined fluid-air evaporator implemented according to the present invention as a refrigerant evaporator, refrigerant is conducted through one of the two duct systems and an exothermic fluid, preferably in the form of a brine, i.e., a glycol-water mixture, for example, is conducted through the other duct system. Alternative exothermic fluid flows may be

provided, for example, in the form of water flows from a lake, well, river, or even in the form of a wastewater flow.

With the aid of the refrigerant evaporator implemented according to the present invention, which may be integrated particularly advantageously as an evaporator unit in a heat pump unit, the heat pump obtains a decisive advantage in regard to reduction of the icing danger at low operating temperatures. In addition, the efficiency of the heat pump increases, since the evaporation temperature is elevated by the additional heat contribution in the evaporator, through which less energy is to be invested in the operation of the heat pump.

Through integration of a heat pump as described above in a ventilation arrangement for a building, multiple extremely interesting and technically simple building aeration and building ventilation constellations having different heating and cooling variations may be provided.

In a ventilation arrangement for a building implemented according to the present invention, a used air flow directed out of the building comes into thermal contact via an air-air heat exchanger with a corresponding outside intake air flow, a combined fluid-air evaporator implemented according to the present invention being provided after the air-air heat exchanger in the flow direction, which the used air flow exiting from the air-air heat exchanger flows over. The combined fluid-air evaporator implemented according to the present invention has, as described above, at least two separate duct systems, which are in thermal contact with one another and through which a refrigerant and an exothermic fluid are each conducted separately from one another, the refrigerant circulating in the loop of a heat pump whose condenser is positioned in the outside air flow after the air-air heat

exchanger in the flow direction. The exothermic fluid permeating the combined fluid-air evaporator, in contrast, circulates in the loop of a heat accumulator system, which preferably has a geothermal collector. However, aerothermal or hydrothermal collector systems are also suitable, using which the heat exploitation of bodies of water, wells, or wastewater is possible.

The main advantage of the ventilation arrangement described above is that the evaporator of the heat pump in the form of the combined fluid-air evaporator implemented according to the present invention has the refrigerant of the heat pump and also at least one further fluid flowing through it, whose heat content is transferred to the refrigerant of the heat pump through direct thermal coupling. In this way, it is possible to significantly reduce the icing danger of the evaporator, particularly at cold ambient temperatures, and in addition the evaporation temperature may be raised, through which the energy input required for heat pump operation may be reduced and, above all, the cooling performance of the heat pump may thus be increased.

The ventilation arrangement implemented according to the present invention additionally offers manifold further advantages in regard to different types of operation as a function of the particular existing ambient temperature conditions. These are to be described in greater detail in the following with reference to the exemplary embodiments.

The suggested integration of the heat pump implemented according to the present invention also allows especially advantageous heating and/or cooling of old buildings, especially since different heat sources may be selected by the combined fluid-air evaporator depending on the outside temperature. For example, the outside air may be used for heating in the transition time (spring/autumn) and at low outside air temperatures, as occur in winter, a ground

collector may be put online. The current hottest heat source is used for the industrial water heating. Combinations of both heat sources are also conceivable. In this way, a constant higher evaporation temperature and, connected therewith, a higher heating performance, may be achieved.

In old buildings, in spite of façade renovation of the building, a high startup temperature is still necessary because of the heating system (usually radiators having 70/55 design). The use of the combined evaporator according to the present invention would allow this requirement to be met more efficiently.

For heating a newer house which is equipped with a lower temperature heater (e.g., floor and/or wall heaters), the combined evaporator, which is integrated in a typical air height and water heat pump, is naturally even more efficient than at high startup temperatures, as in old buildings.

Compact ventilation air conditioners having the combined evaporator are a very efficient solution for use in low energy houses and 3-liter houses due to the advantages described.

#### BRIEF DESCRIPTION OF THE INVENTION

The present invention will be described in the following for exemplary purposes, without restriction of the general idea of the present invention, on the basis of exemplary embodiments with reference to the drawing.

Figure 1 shows a schematic illustration of a combined fluid-air evaporator implemented according to the present invention,

Figure 2 shows a schematic overall illustration of a ventilation arrangement for a building,



Figure 3 shows the illustration according to Figure 2 having an additional solar collector loop,

Figures 4a, b show overall illustrations for a building ventilation arrangement in different operating states.

#### WAYS OF IMPLEMENTING THE INVENTION, COMMERCIAL APPLICABILITY

Figure 1 shows a greatly simplified illustration of a combined fluid-air evaporator implemented according to the present invention, which comprises a coaxial pipeline system that has an external pipe 10 and an internal pipe 11, running coaxially in the interior. As is evident, the relationship  $d_2 < d_1$  applies for the pipe internal diameter  $d_1$  of the pipeline 10 and the pipe internal diameter  $d_2$  of the pipeline 11.

The outer pipeline 10 has a free surface which is in bodily and therefore thermal contact with an air lamellar arrangement 9. In regard to Figure 1, it is assumed that the lamellar bodies 9 intersect the plane of the drawing perpendicularly. An air flow also directed perpendicularly to the plane of the drawing comes into thermal contact with the lamellar bodies 9, which finally causes a heat transfer to both fluid and/or liquid flows passing through the particular pipeline 10 and 11.

The combined fluid-air evaporator is especially advantageously suitable as a refrigerant evaporator, an exothermic fluid, such as brine, being conducted through the pipeline 11 and a refrigerant being conducted through the pipeline 10. Therefore, there is close thermal contact between the refrigerant, the exothermic fluid, and the air flowing around the lamellae 9.

Of course, it is also possible to implement the above thermal coupling between the three material flows using alternative implementations of the combined fluid-air evaporator described above, for example, by providing two identically or differently dimensioned pipelines, which are in bodily and therefore in thermal contact on both sides with the lamellae arrangement 9. Pipelines which have an internal partition wall, through which a single pipeline may be partitioned into two different duct systems, are also conceivable. Of course, further embodiments which implement thermal coupling of different fluid flows are also possible, such as semicircular pipes or pipes having an internal star profile that has multiple ducts.

The combined fluid-air evaporator implemented according to the present invention is especially advantageously suitable as a refrigerant evaporator unit in the framework of a heat pump, which is finally a part of a building ventilation arrangement that will be described in the following with reference to Figure 2.

The ventilation arrangement provided with the reference number 7 shown in Figure 2 essentially comprises two separately directed flow ducts (see flow arrows), which are in thermal contact with one another via an air-air heat exchanger AAH through the transverse flow direction (dashed arrow). Of course, other air-air heat exchanger systems, such as counterflow heat exchangers, for example, are also usable. A used air flow UAF from the building interior thus enters the ventilation arrangement 7, passes the air-air heat exchanger AAH, subsequently flows through the combined fluid-air evaporator 2 implemented according to the present invention and finally exits as exhaust air flow EAF out of the ventilation arrangement 7 into the environment. Furthermore, an outside air flow OAF enters the ventilation arrangement 7 and flows through a fluid-air heat exchanger 1 before the outside air flow OAF passes the

air-air heat exchanger AAH, in which the outside air flow OAF comes into thermal contact with the used air flow UAF. Finally, the outside air flow OAF flows through a condenser 3 following the air-air heat exchanger AAH in the flow direction and finally enters the building interior as the intake air flow IAF.

The interconnection of the combined fluid-air evaporator 2 implemented according to the present invention, which has both an exothermic fluid, preferably brine, that circulates in the loop of a collector 8, such as a ground collector, supported by a pump 4, and also a refrigerant, which passes through the refrigerant loop of a heat pump 6, flowing through it, is of special interest in the ventilation arrangement 7 illustrated in Figure 2. Therefore, the combined fluid-air evaporator 2 is part of the heat pump 6 which additionally comprises the condenser 3. Furthermore, in the exemplary embodiment shown, there is thermal coupling between the heat pump 6 and an industrial water accumulator 5.

The ventilation arrangement illustrated in Figure 2 allows different modes of operation, which may be switched differently with the aid of three-way valves A, B, C within the ground collector loop, for example. The three-way valves illustrated in Figure 2 may also alternatively be replaced by solenoid valves or similar units for deflecting or blocking fluid flows.

It is to be noted in principle that the combined evaporator may be connected to any arbitrary heat source instead of a ground collector, for example, to well water, lake water, wastewater, absorber fencing, solar collectors, etc.. Furthermore, it is possible for different heat sources to be interconnected externally with one another as well, i.e., if there is too little area available for an adequately dimensioned ground collector, for example, the

ground collector may be coupled with well water, for example, through an additional pump and a heat exchanger or even directly, by using a star profile.

Furthermore, it is assumed that the switch position 0 is always open. Thus, as a function of the switch position, the following modes of operation result in regard to the three-way valves A, B, C. Each three-way valve has the switch positions 1, 2, and 0, 0 always being open. For simplification of further speech, the following is assumed: "valve A position 1" means: switch position 1 open, switch position 2 closed. "Valve A position 2" means: switch position 1 closed, switch position 2 open.

If one assumes in the simplest case that the heat pump is switched off and the outside air temperature is lower than the ground collector temperature, the following modes of operation are possible:

It is assumed that valve A is in position 1, valve B is in position 1, and valve C is in position 2. In this case, the fluid-air heat exchanger 1 is used as an outside air preheater and, in addition, as a frost protection device for the following air-air heat exchanger AAH.

If the used air flow UAF passing through the air-air heat exchanger AAH has a temperature which is above the ground collector temperature, in the event of a switch position A position 1, B position 2, C position 1, heating of the ground collector 8 is possible. If the three-way valve A is in position 2, B is in position 1, and C is in position 1, heating of the fluid-air heat exchanger 1 occurs. In contrast, if the three-way valve A is in position 1, B is in position 1, and C is in position 1, there is heating of both the ground collector 8 and also heating of the fluid-air heat exchanger 1.

However, if it is assumed that the heat pump 6 is in operation, targeted heating of the industrial water accumulator 5 and/or the condenser 3 may be performed, for example. This is the case if the three-way valve A is in position 1, B is in position 2, and C is in position 1. For this purpose, the heat pump 6 uses the heat of the ground collector 8 and additionally the used air heat through the thermal coupling between used air UAF and the combined fluid-air evaporator 2 and outputs this heat to the accumulator 5 and/or the condenser 3. If the three-way valve A is in position 1, B is in position 1, and C is in position 2, the used air heat is employed for evaporation during heating operation. If the pump is on "off", the positions of the three-way valves are not relevant. The position 2 is to be recommended for the three-way valve C merely so that no gravity circulation may occur.

If all three three-way valves A, B, C are each in position 1, the ground collector loop 8 is used for prior temperature control of the fluid-air heat exchanger 1, and also for heating the combined fluid-air evaporator 2.

If the ventilation arrangement is to be used for passive cooling in the summer months, the three-way valve A is to be put in position 1, B in position 1, and C in position 2.

In addition, the combined fluid-air evaporator 2 may use the cold used air UAF if the used air temperature is lower than the ground collector temperature, in order to finally cool the fluid-air heat exchanger 1. This is the case if the three-way valve A is in position 2, B is in position 1, and C is in position 1. If the three-way valve A is in position 1, B is in position 2, and C is in position 1, targeted cooling of the ground collector 8 is possible. If both the ground collector 8 and also the fluid heat exchanger 1 are to be cooled under these conditions, the

three-way valve A is to be switched into position 1, B into position 1, and C into position 1.

If the three-way valves A, B, C are activated, cooling using active accumulator heating may be performed if the three-way valve A is in position 2, B is in position 1, and C is in position 1, heating of the industrial water accumulator 5 occurring and the combined fluid-air evaporator 2 being cooled by the heat pump. The cooled fluid is now pumped to the fluid heat exchanger 1, which may in turn actively cool the outside air.

If the switch position A is in position 2, B is in position 1, and C is in position 1, the combined fluid-air evaporator 2 is cooled by the heat pump 6. The cooled fluid is now pumped to the fluid-air heat exchanger 1, which cools the outside air. If the industrial water accumulator 5 may not absorb any more heat, the heat arising at the condenser 3 may be dissipated in the direction of the exhaust air through corresponding mixing of the intake air flow. This is possible through appropriate flaps, for example, using which the intake air flow is conducted into the exhaust air. If dissipation of the condenser heat through deflection into the exhaust air is not possible, as may be the case if the measures required for this purpose are too expensive, the heat may be dissipated in a targeted way to the surrounding air by providing an additional condenser in the outside area. This would be necessary if there is no industrial water accumulator or no buffer accumulator and active cooling is nonetheless to be performed.

Figure 3 shows an implementation of the ventilation arrangement expanded in relation to Figure 2 through combination with a solar collector 14, whose collector flow loop is coupled with the ground collector flow loop in the way indicated, through which additional heat is obtained

for preheating the outside air OAF. If, for example, in the event of low solar radiation, the temperature increase achievable using a solar collector 14 is insufficient for heating the industrial water accumulator 5, via a corresponding valve position of valve D, the heat flow of the collector flow may be coupled to the ground collector loop in order to additionally heat the fluid-air heat exchanger 1, for example. The solar collector loop shown in Figure 3 may additionally be combined with the fluid loop of the combined fluid-air evaporator 2 by attaching a valve. However, this requires suitable valve measures, through which it would additionally be possible to thermally couple the solar collector loop, in combination or in an alternative position, with the fluid-air heat exchanger 1 and the combined fluid-air evaporator 2.

A further operational possibility for the ventilation arrangement 7 is illustrated in Figures 4a and 4b, which provides a unit 12 deflecting the flow implemented in the form of a flap directly before the combined fluid-air evaporator 2 in the flow direction. For example, if there are very low outside air and used air temperatures, it may be advantageous for the efficiency of the combined fluid-air evaporator 2 to conduct the cold used air flow past the combined fluid-air evaporator 2 via a bypass channel 13 by closing the flap 12 (see Figure 4b). In this operating position, the combined fluid-air evaporator 2 exclusively has its temperature controlled by the exothermic fluid which circulates in the loop of the ground collector 8. In the flap position illustrated in Figure 4a, the bypass channel 13 is closed, through which free flow of the used air UAF through the combined fluid-air evaporator 2 is ensured. If heat pump 4 is switched to "on", and the three-way valve A is in position 1, B is in position 1 (2 is also possible), and C is in position 1, simultaneous operation of the combined evaporator using used air and brine is possible. The flap position 12 may also be

constructed so that only the bypass channel 13 is closed or opened, for example, and there is always a flow through the combined evaporator. It is also possible to achieve partial flow through other flap constructions, for example, i.e., a part of the air through the bypass channel 13 and a part through the combined fluid-air evaporator 2.

A further alternative embodiment variation for the ventilation arrangement is illustrated in Figure 5a. The alternative refinement relates to the refrigerant loop of the heat pump 6.

Normally, in the refrigerant loop of a heat pump, the refrigerant gas is compressed at a high temperature and is pumped, for example, to the condenser for industrial water heating 5 and/or to the air condenser 3 for air heating. The refrigerant condenses there and, in most cases, reaches an internal heat exchanger within the heat pump 6, the recuperator, which increases the suction gas temperature and therefore the degree of overheating after the evaporator in order to avoid liquid refrigerant not being suctioned into the compressor. Frequently, further components such as collectors and dryers are positioned downstream from the recuperator. The refrigerant finally reaches an expansion unit, through which it is relaxed, through which temperature and pressure are reduced. In the evaporator, the refrigerant again absorbs heat from the heat source and reaches the compressor. The loop begins again.

However, it has been shown that the refrigerant has significant heat energy before the expansion valve, which has remained unexploited until now. Therefore, it is advantageously suggested that an additional heat exchanger be provided between the recuperator and the expansion unit, through which heat is withdrawn from the refrigerant. In this way, the cooling performance of the heat pump may be



increased largely without the use of additional electrical energy. The refrigerant must naturally flow through this additional heat exchanger in order to be able to transport off the heat.

Following this idea, refining the fluid-air heat exchanger 1 according to the exemplary embodiment in Figure 5 suggests itself. The preheating for the outside air OAF may thus be performed by a commercially available heat exchanger, which provides two loops 15, 16. For this purpose, a schematic heat exchanger 1 is shown in Figure 5b, which the outside air OAF flows through and which has a loop 15 with the brine flowing through it and a loop 16 with the refrigerant flowing through it. The loop 15 dissipates the heat or cold to the outside air flow OAF. The loop 16 which the refrigerant flows through dissipates the heat from the refrigerant to the outside air flow OAF and thus increases the degree of undercooling.

An array of advantages is connected with the ventilation arrangement implemented according to the present invention as described above, which will be referred to in sequence in the following:

A changeover of the heat pump in the refrigerant loop between cooling and heating operation is completely dispensed with, through which previously known weak points, such as providing four-way valves or solenoid valves, are dispensed with. The changeover now occurs in the loop of the heat accumulator, for example, of the geothermal loop.

By dispensing with the previously required changeover of the heat pump between cooling and heating operation, a more stable cooling loop is ensured and a significantly higher performance number is possible.

The energy invested in the heat pump may be exploited more efficiently.

No energy losses arise in cooling operation, since the industrial water accumulator or another accumulator may be heated in this case. The heat may also be dissipated to a typical heater, however.

The possibility exists of using two or more heat sources, so that a largely constant temperature exists in the evaporator, which finally results in a higher performance number of the heat pump. A longer service life of the heat pump is also achievable, especially if the compressor output of the heat pump may be reduced.

Simpler heat pump construction is achieved through simpler pipe direction and the use of less refrigerant, since fewer pipes and valves are necessary. Through targeted heat exploitation of the used air, the energy may be converted more efficiently. If the ground collector 8 is laid out correspondingly large, the combined fluid-air evaporator may use the heat for evaporation effectively, through which the icing danger may be nearly excluded. The fluid-air heat exchanger 1 may be heated simultaneously, through which the icing danger may also be avoided at the fluid-air heat exchanger.

Incorporation of an additional solar collector is also easily possible, since the collector flow and also a ground collector flow are materially identical and may be operated under identical pressure conditions. Even in the case of different pressure levels and fluids in the solar collector loop and ground collector loop, both loops may be thermally coupled using plate heat exchangers.

List of reference numbers

- 1 fluid-air heat exchanger
- 2 combined fluid-air evaporator
- 3 condenser
- 4 pump
- 5 industrial water accumulator
- 6 heat pump
- 7 ventilation device
- 8 ground collector (heat accumulator)
- 9 lamellae
- 10 outer pipeline
- 11 inner pipeline
- 12 flap
- 13 bypass line, used air bypass, bypass duct
- 14 solar collector
- 15 loop
- 16 loop
- A, B, C three-way valves
- UAF used air flow
- OAF outside air flow
- EAF exhaust air flow
- IAF intake air flow
- AAH air-air heat exchanger